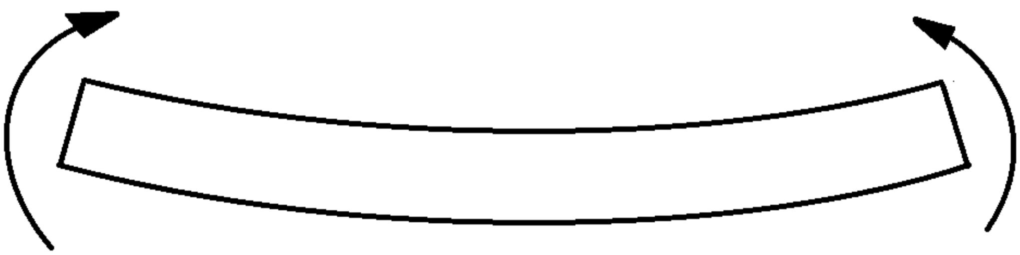
University of Menoufia
Shebin El-Kom
Civil Engineering

Research on

"Behavior Of Beams Under Bending Forces"



***This research work is under the supervision of <u>Dr.Boshra El-Taly</u>**

Table of Contents:

Introduction

A beam is a structural element used for bearing loads. It is typically used for resisting vertical loads, shear forces and bending moments.

They are important type of structural members (floors, bridges, roofs) and usually long, straight and rectangular , the length of it is considerably longer than the width and the thickness

Beams can be classified into many types based on three main criteria. They are as follows:

1. **Based on geometry:**
    1. Straight beam – Beam with straight profile
    2. Curved beam – Beam with curved profile
    3. Tapered beam – Beam with tapered cross section
    4. Based on the shape of cross section such as : T-beam, **Fig.(1)**

2. **Based on equilibrium conditions:**
    1. Statically determinate beam – For a statically determinate beam, equilibrium conditions alone can be used to solve reactions.
    2. Statically indeterminate beam – For a statically indeterminate beam, equilibrium conditions are not enough to solve reactions. Additional deflections are needed to solve reactions.

3. **Based on the type of support :**
    1. Simply supported beam : a beam supported on the ends which are free to rotate and have no moment resistance
    2. Overhanging beam : a simple beam extending beyond its support on one end.
    3. Continuous beam : a beam extending over more than two supports.
    4. Cantilever beam : a projecting beam fixed only at one end.
    5. Fixed beam : a beam supported on both ends and restrained from rotation **Fig.(2)**

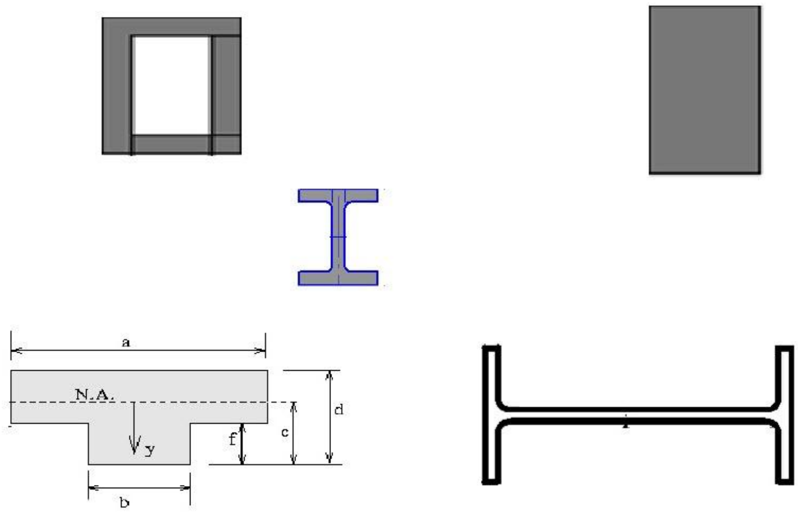


Fig.(1.0) Shapes of beam cross sections

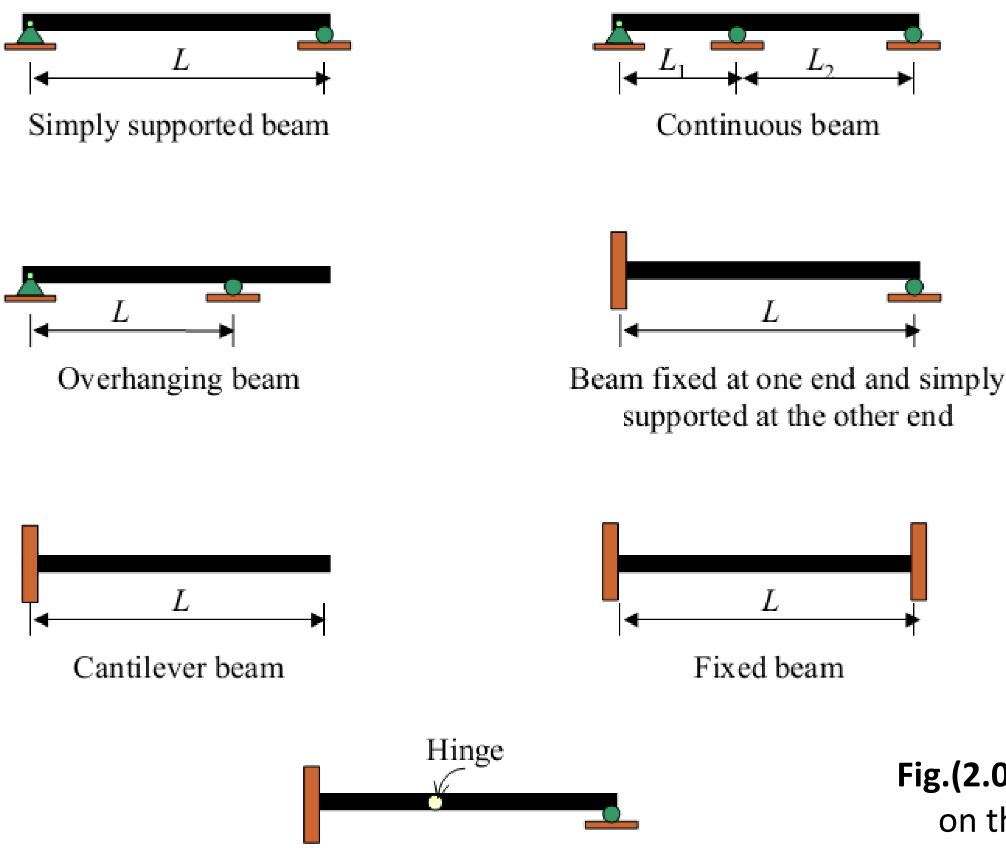


Fig.(2.0) Beams types based on the type of support

*What is Loading?

Loading is the process in which loads are applied on beams which causes internal forces in them.

Different loads acting on beams:-

- Dead Load : Stationary loads or permanent loads
- Live Load : Moving loads
- Wind Load : Loads due to wind
- Snow Load : Load due to snowfall
- Seismic Load : Effect due to earthquakes

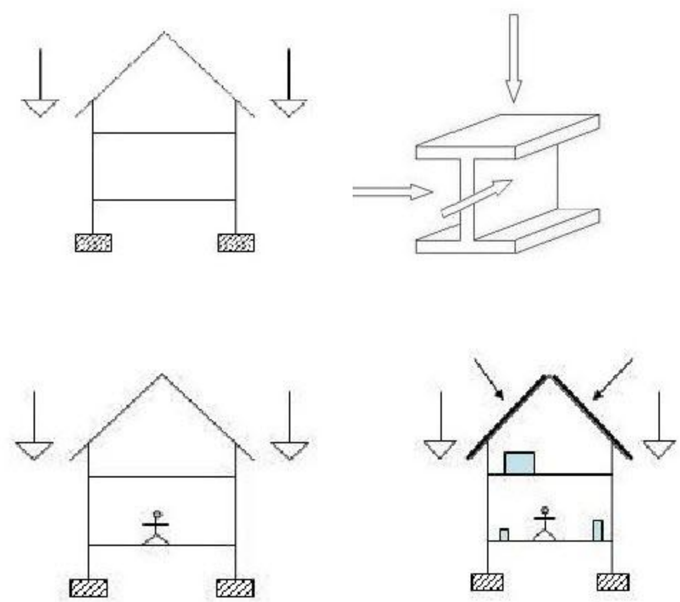


Fig.(3.0) Types of loads

Types of Loads w.r.t Their Actions:

- \- Concentrated – single load, single moment
- \- Distributed – loading spread over a distance, uniform or non-uniform

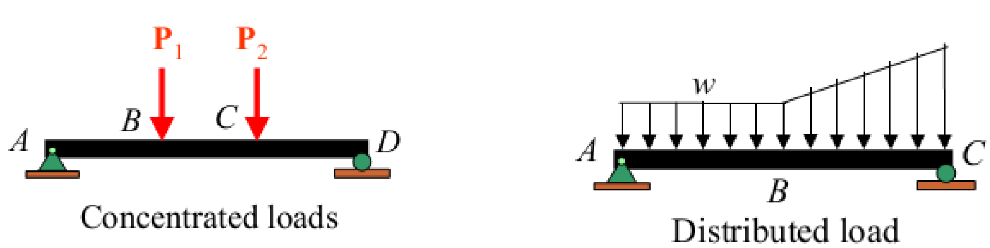


Fig.(4.0) Load actions

Applications of Beams :

- Beams are used everywhere where horizontal support is required.
- It takes the load and transfer to the columns or load bearing walls.
- Used for frame structure of building.
- Used in bridges for supporting the slabs beneath it as a frame structure

➢ Let's talk about Forces

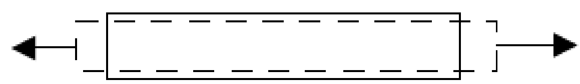
Force : is any influence that causes an object to undergo a certain change, either concerning its movement, direction, or geometrical construction. In other words, a force can cause an object with mass to change its velocity to accelerate, or a flexible object to deform. <u>And the later concept is which we are talking about.</u>

Types of Forces And Deformation:

External forces or loads cause internal stresses to be set up in a structure. Not all forces or loads act in the same way. Forces can bend, pull, press, or twist. Each of these types of force are given special names :

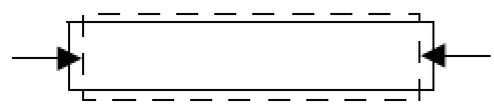
Tension -

The member is being stretched by the axial force.
The deformation is characterized by axial elongation (the act of lengthening something)
A structural member in tension is called a tie.
A Tie resists tensile stress



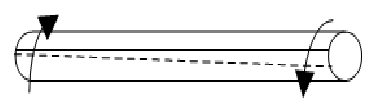
Compression -

The member is being compressed by the axial force and is in compression.The deformation is characterized by axial shortening. A structural member in compression is called a strut.
A strut resists compressive stress.



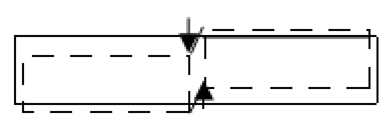
Torsion -

The member is being twisted and is in torsion.
The deformation is characterized by angle of twist



Shear -

A shear force is created where two opposite forces try to cut tear or rip something in two.
The deformation is characterized by alter shape of a rectangle into a parallelogram.



Bending -

The member is being bent .The deformation is characterized by a bent shape stretched and squashed at the same time

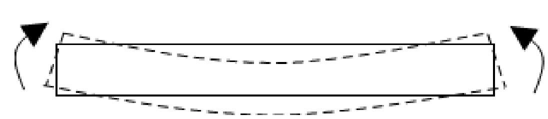


Fig.(5) Types of Forces on beams

Forces that cause bending

Forces that Cause bending
- Shearing forces
- Non axial normal forces
- Bending moment

1.Shearing Force : Q

A shear force is an internal force that is parallel to the section it is acting on and that resists the vertical effect of the applied loads on the beam. The shear force is numerically equal to the algebraic sum of all the vertical forces acting on the free body taken from either sides of the section.

2.Non Axial Normal Forces

If the axial load is applied such that its line of action is not on the neutral axis, then this axial load results in bending.

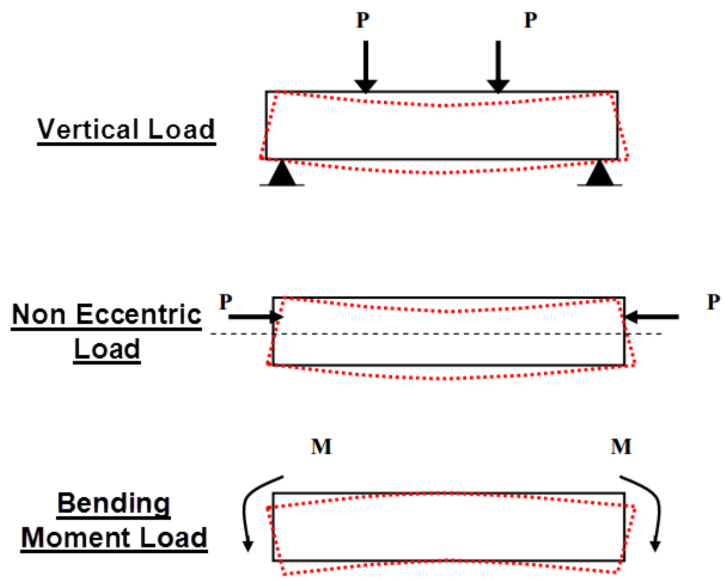


Fig.(6.0) Forces that Cause bending

3.Bending Moment : M

- is the bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads.
- is a term used to describe the force or torque that is exerted on a material and leads to the event of bending or flexure within that material. It is a type of stress and is measured in terms of force and distance..

*How does bending moment produce?

The *internal stresses* in a cross-section of a structural element can be resolved into a resultant force and a resultant couple. For **equilibrium**, the moment created by *external forces* must be balanced by the couple induced by the internal stresses. The resultant internal couple is called the bending moment while the resultant internal force is called the shear force (if it is transverse to the plane of element) or the normal force (if it is along the plane of the element).

The bending moment at a section through a structural element may be defined as " the algebraic sum of the moment of the forces to the left or to the right of the section taken about the section" or "is the sum of: each external force multiplied by the distance that is perpendicular to the direction of the force."

MOMENT (Nm) = FORCE (N) x DISTANCE (m)

Determining the bending moment is important to determining how much pressure a beam can withstand without experiencing any type of sagging or breakage.

For this reason, structural engineers - often look closely at the performance of different materials when designing a building, dam, or other structure, using the data to determine which materials to use and in what measure to achieve the desired effect.

***Sign conventions:**

If the moment on the left side is <u>clockwise</u> and the moment on the right side is anti-clockwise**, sagging** results and the bending moment is said to be <u>positive</u> **.**

If the moment on the left side is <u>anti-clockwise</u> and the moment on the right clockwise**, hogging** occurs and the bending moment is said to be <u>negative</u>. **(Fig. 7)**

Fig.(7.0) Moment sign and effect

==

Stresses

Stress can be defined as the intensity of internal force that represents internal force per unit area at a point on a cross-section.

Stresses are usually different from point to point. There are two types of stresses, namely normal and shear stresses.

Bending Stress

Bending produces reactive forces inside a beam as the beam attempts to accommodate the flexural load: in the case of the beam in **Fig. (8.0)**, the material at the top of the beam is being compressed while the material at the bottom is being stretched. There are three notable internal forces caused by lateral loads **Fig. (9.0) ,** shear parallel to the lateral loading, compression along the top of the beam, and tension along the bottom of the beam. These last two forces form a couple or moment as they are equal in magnitude and opposite in direction.This bending moment produce the sagging deformation or stress.

This stress distribution is dependent on a number of assumptions: First, that plane sections remain plane. In other-words, any deformation do to shear across the section is not accounted for (no shear deformation).Also,this linear distribution is only applicable if the maximum stress is less than the yield of-the-material (Hook’s law), and section of the beam is hemogenous.

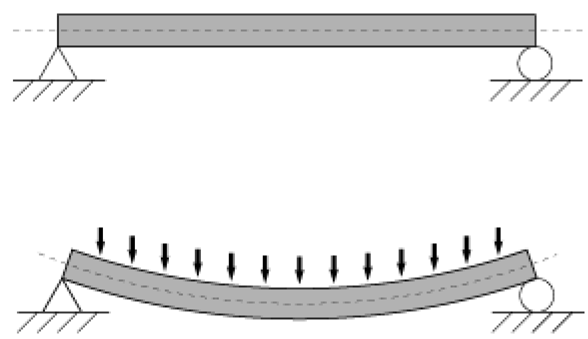


Fig.(8.0) Beams behavior under forces

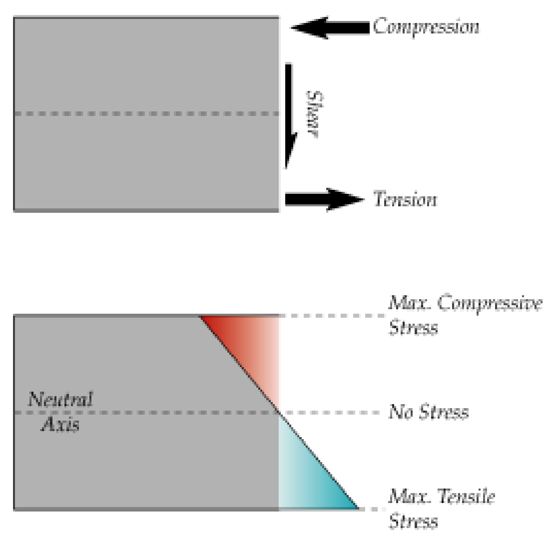


Fig.(9.0) Internal forces caused by lateral loads

The compressive and tensile forces shown in **Fig. (9.0) ,**induce stresses on the beam. The maximum compressive stress is found at the uppermost edge of the beam while the maximum tensile stress is located at the lower edge of the beam. Since the stresses between these two opposing vary linearly, there therefore exists a point on the linear path between them where there is no bending stress. The locus of these points is the neutral axis.

Note: Because of this area with no stress and the adjacent areas with low stress, using uniform cross section beams in bending is not a particularly efficient means of supporting a load as it does not use the full capacity of the beam until it is on the brink of collapse. <u>(T-Beams) with Hollow Blocks</u> effectively address this inefficiency as they minimize the amount of material in this under-stressed region.

*The General Bending Equation

The bending moments Mx and My cause the beam to bend.

Stresses are present in the beam. can be calculated from this equation :

$$\sigma = \left(\frac{MyIxx \ - MxIxy}{IxxIyy - Ixy^{\,2}}\right)x \ + \left(\frac{MxIyy \ - MyIxy}{IxxIyy - Ixy^{\,2}}\right)y$$

If the cross-section of the beam is symmetric about the x-axis or about the y-axis (or both), then we have Ixy= 0. This simplifies the above equation. We then remain with :

$$\sigma = \frac{Mx}{Ixx}y \ + \frac{My}{Iyy}x$$

σ_z – Bending stress

M – Calculated bending moment

y – Vertical distance away from the neutral axis

x - Horizontal distance away from the neutral axis

I – Moment of inertia around the neutral axis

For Beams the most common equation is :

$$\sigma = \frac{MY}{I}$$

M = bending moment
I = moment of inertia (in^4 or mm^4)
y = distance from neutral axis

==================================

Bending Tests

Bend and Flexure Tests

They allow for the determination of the material ductility, modulus of rupture,bend strength, stiffness, resilience and resistance to fracture. These characteristics can be used to determine whether a material will fail under pressure and are especially important in any construction process involving materials loaded with bending forces. Flexure Test is common in brittle materials whose failure behaviours are linear such as concretes, stones, woods, and ceramics. Bend Test is similar to the flexure one in the type of hardware and test procedure involved,but bend tests are used with ductile materials whereas flexural tests are used with brittle materials.

Flexure Test Types:

The two most common types of flexure test are :

Three (or centre) & Four (or two) point flexure bending tests.

1.The three point bend test:

- It consists of the sample placed horizontally upon two points and the force applied to the top of the sample through a single point so that the sample is bent in the shape of a "V". **Fig.(10.0-a)** .
- It is ideal for the testing of a specific location of the sample.
- In it, the maximum moment occurs at the midpoint.
- It applies where the material is homogeneous, such as plastic materials. The stress concentration of it is small and concentrated under the center of the loading point.
- The deflection measurement is commonly measured using the machine's crosshead position sensor (typically a digital encoder)

2.The four point bend test:

- A four point bend test is roughly the same except that instead of the force applied through a single point on top it is applied through two points so that the sample experiences contact at four different points and is bent more in the shape of a "U". **Fig.(10.0-b).**
- It is more suited towards the testing of a large section of the sample, which highlights the defects of the sample better than a 3-point bending test.
- It tends to be the best choice if the material is not homogeneous, such as composites or wood.
- The stress concentration of it is over a larger region, avoiding premature failure.
- In it, the maximum moment occurs over the area between loading points.
- It is commonly measured using a deflectometer.

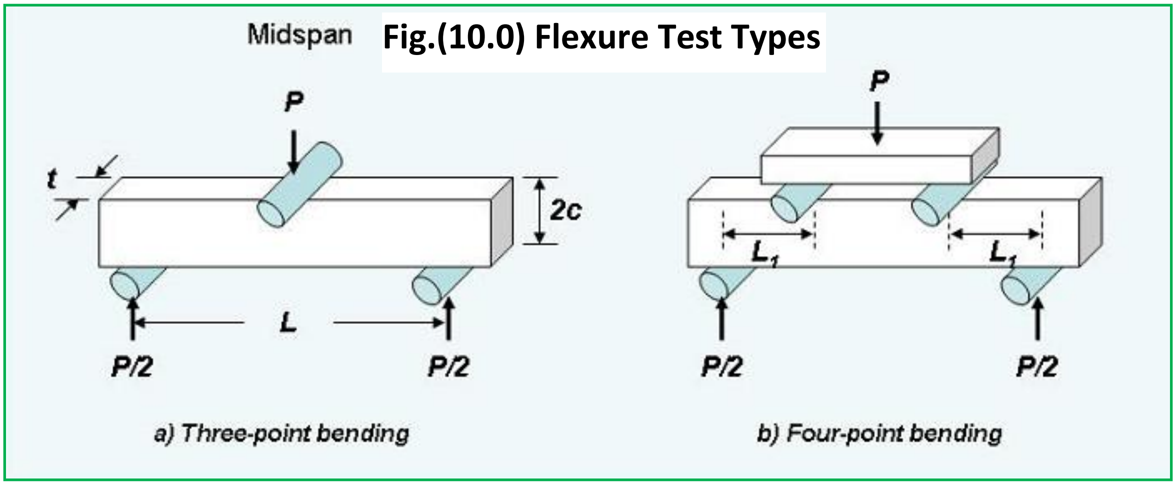


Fig.(10.0) Flexure Test Types

Four-point bend testing is better because it makes the beam part in which the fracture happens to be affected by bending only and deformations and displacements take place in **Pure Bending*** without the presence of shear influence. So it gives a more accurate value of the flexure strength of the composite. **Fig.(11),** shows the moment diagram in both types. *Beam is said to be in a state of <u>pure bending</u> when the shear force is zero.

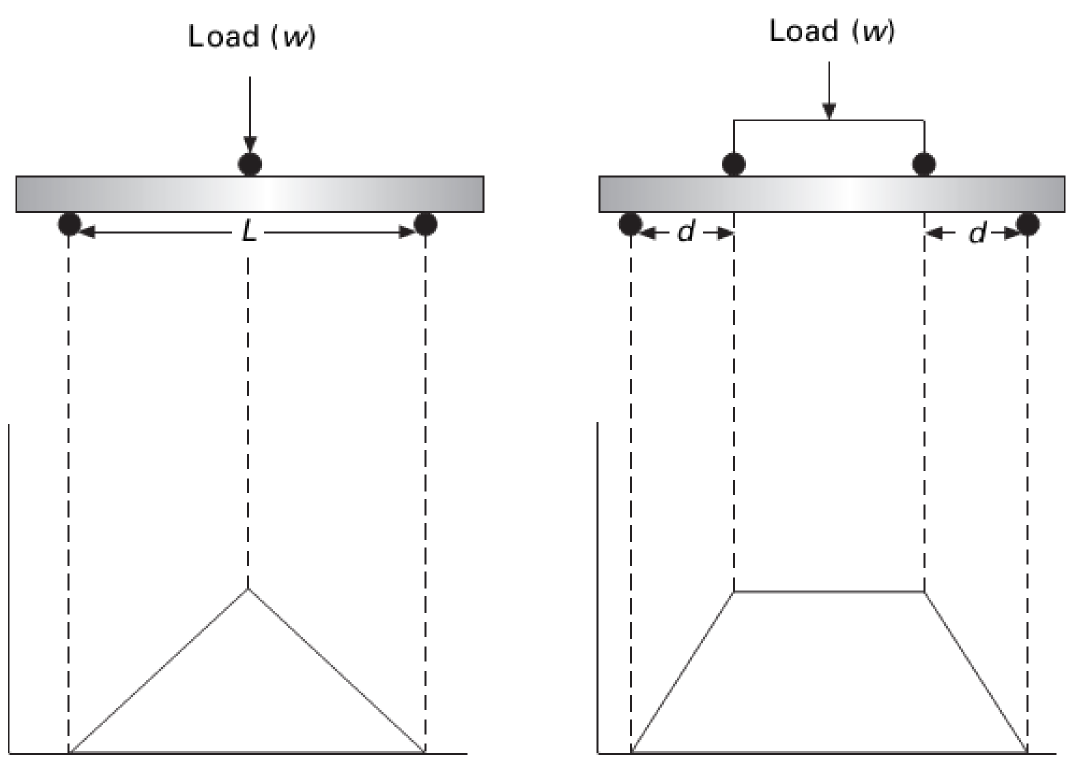


Fig.(11.0) Moment Diagrams

Test Specimens :-

Smooth rectangular specimens without notches are generally used for bend testing. We may use different shapes of beams with standard Dimensions as specimens in the some researches and scientific experiment.

To be suitable for bending test, The sample beam length (L) must be as equal 6 - 12 times as the depth (D) of it ... **L=6d to 12d**

Test Machines :-

Test machines for flexural bend tests of concrete beams must have a high force capacity. Small displacements correspond to large force increases for concrete, so machine actuators and controls must be able to apply this increasing force without significant oscillation, around the desired force, caused by crosshead vibration.

<u>Major Parts :</u>

* Support pins
They must be free in motion so that the stresses can’t concentrate at them, Standards States that they are a big metal rollers and a piece of rubber or wood is put between them and the tested beam.

* Loading pins
The points of loading must have the same conditions of supports until load distribution is uniform,they may be in the mid-beam or where the loading span is one-third of the support span.

* Load rate screen

* Strain measurement parts or bending indicators.

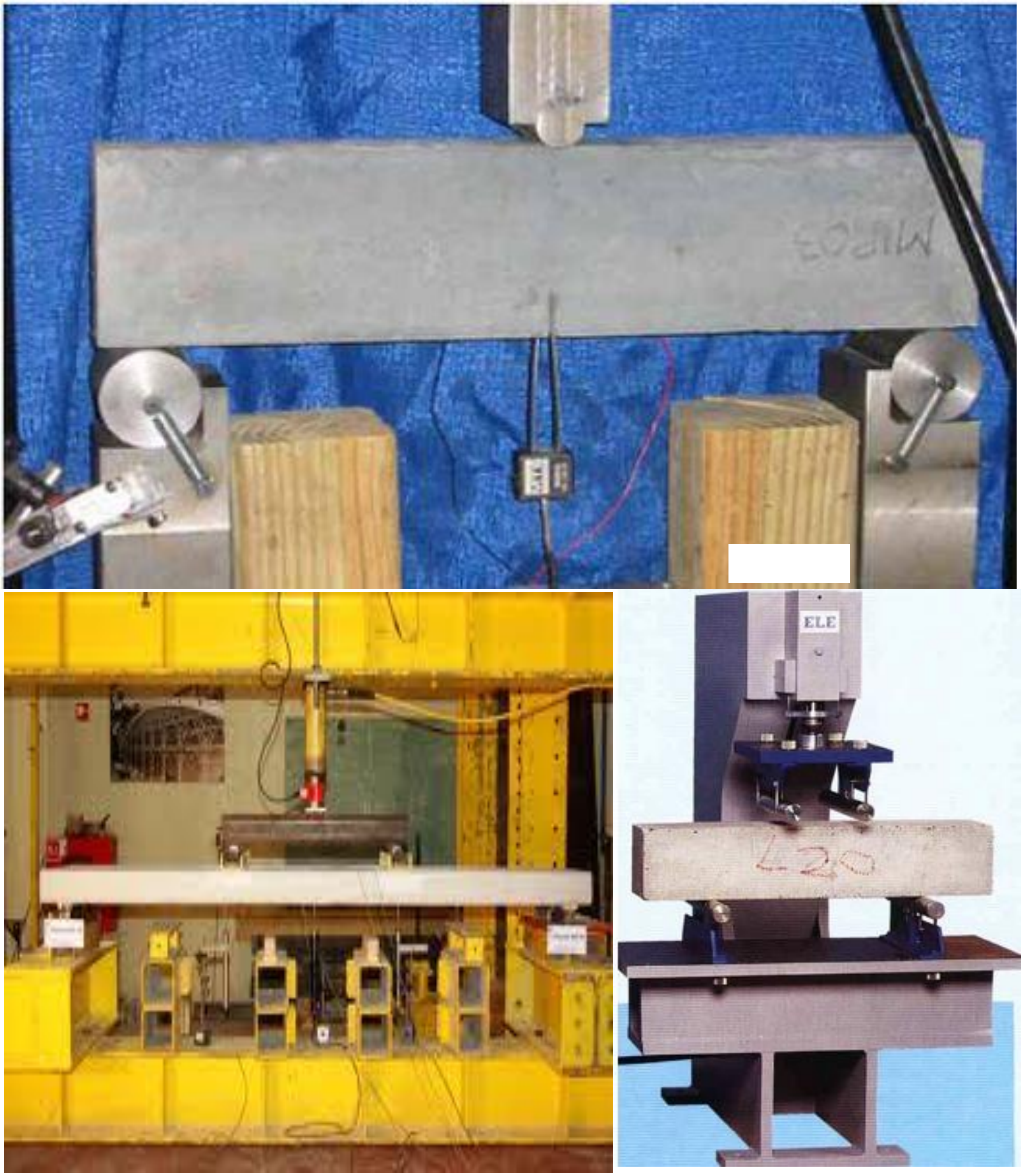


Fig.(12.0) Machines of Bending Testing

Some of mechanical properties :

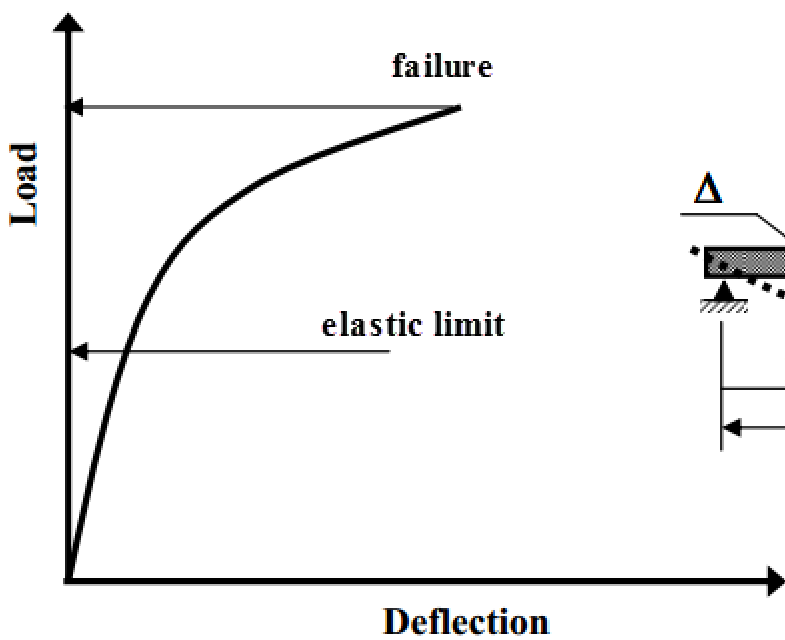
After acting the flexure test and drawing *load-deflection* curve,we can calculate some mechanical properties :

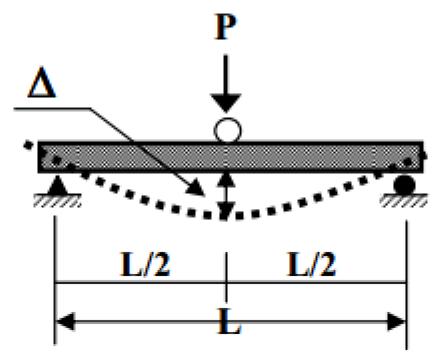
1. Bend Strength

it is defined as a material's ability to resist deformation under load. It is measured in terms of stress.

It can be calculated by equation where stress is (stress of the elastic limit) **:**

$$\sigma = \frac{MY}{I}$$





2. Toughness

It is the amount of energy per volume that a material can absorb before rupturing. It is also defined as the resistance to fracture of a material when stressed. It can be calculated by integrating the load-deflection curve.

3. Modulus Of Rupture

-It is breaking strength in a brittle solid as measured by bending.
-It is the maximum surface stress in a bent beam at the instant of failure.

<u>It can be calculated equations:</u>

*Under a load in a three-point bending:

$$\sigma = \frac{3FL}{2bd^2}$$

*Under a load in a four-point bending setup where the loading span is one-third of the support span:

$$\sigma = \frac{FL}{bd^2}$$

- F is the load (force) at the fracture point
- L is the length of the support (outer) span
- b is width ,d is thickness

4. Resilience

It is the ability of a material to absorb energy when it is deformed elastically, and release that energy upon unloading.It can be expressed by *Modulus Of Resilience* that is the maximum energy that can be absorbed per unit volume without creating a permanent distortion.

<u>It can be calculated by integrating the stress-strain curve from zero to the elastic limit.</u>

5. Stiffness

It is the extent to which it resists deformation in response to an applied force. It can be expressed by *Flexural Modulus* that is the slope of a stress / strain curve in the elastic region.
<u>It can be calculated by the modulus of elasticity by equations:</u>

*Under a load in a three-point bending:

$$E = \frac{PL^3}{48 \vartriangle I}$$

*Under a load in a four-point bending setup where the loading span is one-third of the support span:

$$E = \frac{23PL^3}{1296 \vartriangle I}$$

****

*****

**

References:

I. Hibbleler, R.C., Mechanics Of Materials

II. Jianqiao Ye ,Structural and Stress Analysis: Theories, Tutorials and Examples

III. خواص المواد واختبارتها أ.د محمود إمام- أ.د محمد مهدى- أ.د محمد أمين

IV. Wikipedia.org

V. Testresources.net

تم بحمد الله ,,

Names of The Participants in the research

Sec.7-Group2

Name	No.
مصطفى محمود كامل اسماعيل	1
منة اللّه فتحى حسن السيد	2
نادية علام شعبان علام	3
نعمة عبد اللاه محمد الجوهرى	4
نورهان على محمد صالح	5
هاجر عزت عبد الرحمن السيد صقر	6
هاجر مسعد أمين البمبى	7
هانى سعيد العليمى أحمد عمر	8
هانى محمد سعيد عبد الهادى عبد الجواد	9
هبة أيمن محمود السيد الاودن	10
هبة يوسف فؤاد يوسف أبو الفرج	11
هدير السيد محمد الكفراوى السيد	12
ياسمين أحمد على السبروت	13
ياسين سمير إبراهيم الدجهومى	14
يسرى أحمد عبد العزيز أحمد شاهين	15
يوسف صبحى مهدى السيد عزب	16